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THE CHANGING FLORA OF THE SHOALWATER BAY ISLANDS

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ABSTRACT

A survey on the flora of the Shoalwater Bay islands was conducted and compared with previous surveys dating back to 1959. Vegetation cover has varied on Penguin Island, as assessed by examination of aerial photographs, but is now in reasonable condition. Penguin Island has shown some turnover of species, especially annual aliens, but total species numbers have changed little. There has been a serious loss of species on the smaller islands with total devegetation of West Shag Island. Reduction in species variety seems most serious in Seal Island and Bird Island where there has been marked loss of native perennial species. In these two islands there has been extensive influx of aliens with large forests of *Lavatera arborea*, over 2 metres in height, and smaller stands of *Malva parviflora* which have replaced the original vegetation. Invasion by these weeds and others is noticeable on Penguin Island but is proportionately less. African Boxthorn (*Lycium ferocissimum*) has been noted for the first time on Penguin Island.

INTRODUCTION

The Shoalwater Bay Islands include Penguin Island, which with an area of 12.5 hectares is by

far the largest, and then in descending order of size, Seal Island, Bird Island, Middle, West and East Shag Islands and Gull Rock. There are also a few smaller

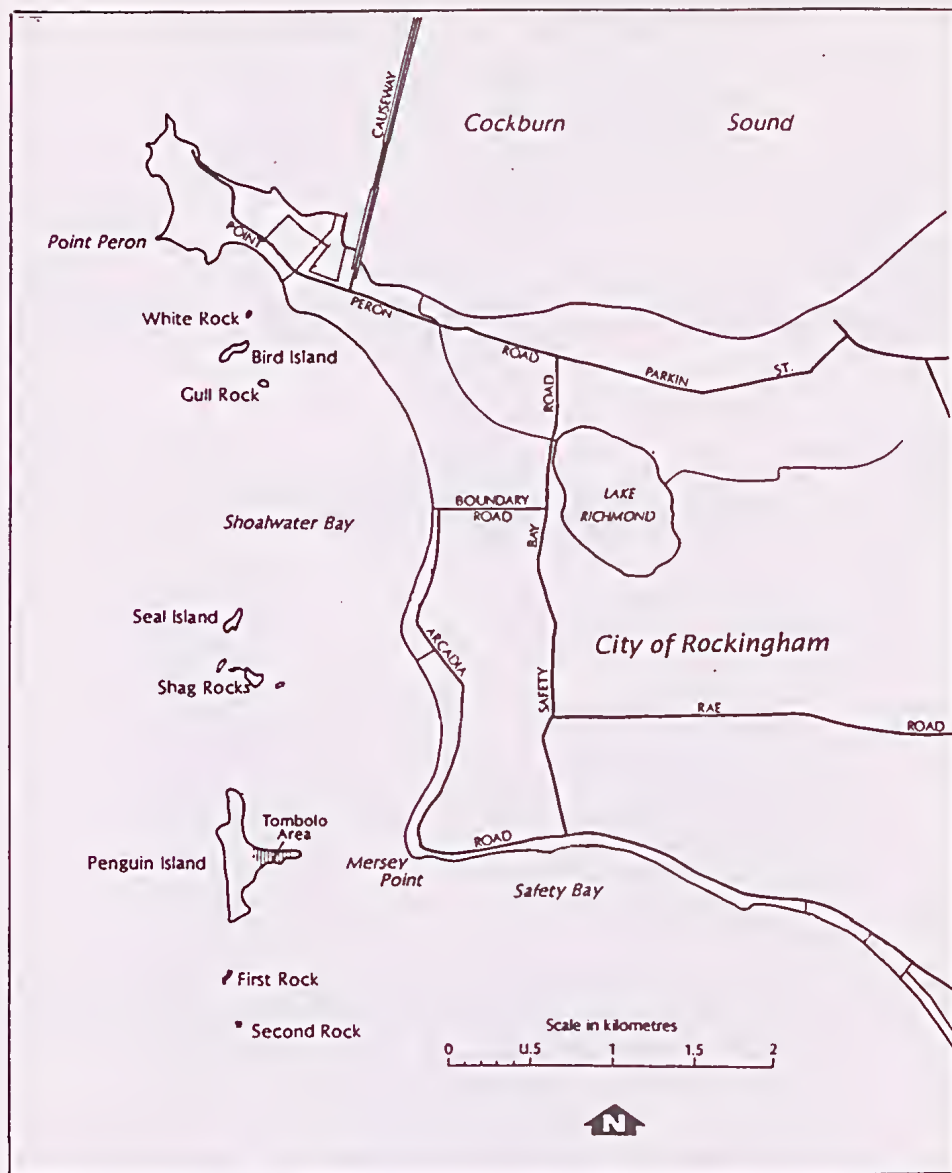


Figure 1. Locality map.

named rocks which have not been considered in surveys (Figure 1). Since 1992 these islands have been included in the bounds of the Shoalwater Islands Marine Park. Prior to 1987, when the

Department of Conservation and Land Management (CALM) took over the lease of Penguin Island it had been used as a holiday island. In October 1997 the Friends of the Shoalwater Islands Marine Park

(FSIMP) conducted a vegetation survey of the islands as a part of a monitoring operation. The results of previous surveys (Storr 1961; Abbott and Black 1980 and Chape 1984) were available for comparative purposes.

MATERIALS AND METHODS

Aerial photographs of all islands were obtained from the Department of Land Administration, as well as photocopies of black and white aerial photographs of Penguin Island from the years 1953, 1963, 1975, 1980 and 1987 (all the years available during earlier vegetation surveys).

FSIMP members carried out a complete flora survey of Penguin Island, Seal Island, Bird Island, Middle, West & East Shag Islands and Gull Rock (Figure 1). Quantitative vegetation assessment was carried out only on Penguin Island as this larger island had significant areas of all plant habitats.

Field work on Penguin Island was substantially completed on 25 and 26 October 1997. Teams of FSIMP members were sent to collect specimens of all plants from four broad habitat areas on the island, the northern plateau, southern plateau, central dune-field and the tombolo. Planted species cultivated in the tombolo area were not collected unless there was evidence of invasion of the natural vegetation. Specimens were identified or given a field number, pressed for expert verification and the compilation of a permanent reference herbarium and used to create four

standard field herbaria (i.e. one for each broad habitat area).

Once the field herbaria were complete the teams returned to their broad habitat areas to carry out belt transect sampling. Transects were broadly orientated east-west across the island and consisted of a chain of plots 2m wide by 5m in length. Nine transects varying in length from 45m to 200m were completed. The locations of these transects are shown on Figure 2.

A complete list of plant species was recorded for each plot and the distribution of species with high coverage was sketched onto a plot

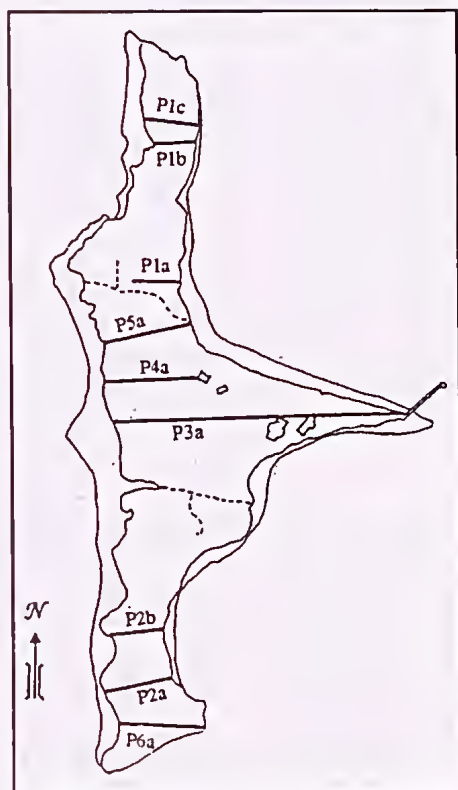


Figure 2. Penguin Island – transects.

outline. Also recorded were the slope, aspect, soil depth and rock exposure within each plot.

In the week following the Penguin Island field work all the smaller islands in Shoalwater Bay were surveyed by FSIMP members. All plants present on each island were collected and identified by reference to the field herbaria. Species lists were then produced for each island for comparison with available historical surveys.

RESULTS

Vegetation cover of Penguin Island varied considerably over the years. It was much reduced in 1953 when the first aerial photographs were taken.

There was gradual improvement until 1975. However the ground cover again appeared depleted in 1980 but was recovering by 1983. In 1997 even further improvement could be seen.

The 1997 flora survey recorded 77 plant species on the Shoalwater Bay Islands (Appendices 1 & 2). Of these 38 (+50%) were indigenous plants, the majority of which were woody or succulent perennial

shrubs. Half the flora consisted of introduced species including short-lived woody perennials, herbs and grasses.

The flora of Penguin Island has been surveyed on three previous occasions and the smaller islands were included in the first two of those studies (Storr 1961, Abbott and Black 1980 & Chape 1984). Table 1 compares the number of species observed on each island during the present survey with the number recorded in historical surveys.

It shows that the number of plant species on the larger Penguin Island has apparently fluctuated within a narrow range over time but has in effect changed little over the past 30 years. Conversely plant species richness on the smaller islands has undergone a dramatic decline. The only plant species discovered on the smaller islands which was not present on Penguin Island was the native Hollyhock *Lavatera plebeia*.

Table 2 shows the changes in the number of indigenous species on all the islands. Penguin Island has lost 5 (12%) indigenous taxa since the earliest surveys. However the

Table 1. Number of species found in each survey

Island	Area (ha)	1959 ¹	1975 ²	1984 ³	1997 ⁴
Penguin	12.5	71	81	71	76
Seal	1.2	41	32		17
Bird	0.9	31	31		14
M Shag	0.4	24	22		16
W Shag	0.16	6	12		0
E Shag	0.04	4	6		1
Gull Rock	0.04	2	5		1

Table 2. Number of native species found in each survey

Island	1959 ¹	1975 ²	1984 ³	1997 ⁴	Total species	Species common to all
Penguin	42	43	39	37	51	26
Seal	24	17		8	25	8
Bird	17	16		3	18	3
M Shag	14	11		8	16	7
W Shag	6	7		0	7	0
E Shag	4	5		1	5	1
Gull Rock	2	4		1	4	1

1959¹ – Storr (1961)1975² – Abbott and Black (1980)1984³ – Chape (1984)1997⁴ – current study

loss of indigenous flora on the smaller islands was much more significant – 16 (67%) on Seal, 14 (82 %) on Bird, 6 (43%) on Middle Shag, 6 (100%) on West Shag, 3 (75%) on East Shag and 1 (50%) on Gull Rock.

The indigenous plant species apparently lost from the Shoalwater Islands include *Isolepis marginata* and *nodosa*, *Sarcocornia blackiana*, *Calandrinia calypttrata*, *Anthocercis littorea*, and *Angianthus cunninghamii*.

One indigenous species has appeared on Penguin Island since 1961; this is the grass *Austrostipa elegantissima* which is now abundant on the lee slope of the central dune. The weeds which have been introduced to the islands since 1961 include *Urtica urens*, *Atriplex prostrata*, *Chenopodium ambrosioides*, *Sagina maritima*, *Fumaria capreolata*, *Brassica rapa*, *Rhaphanus raphanistrum*, *Erodium moschatum*, *Lavatera arborea*, *Lavatera cretica*, *Malva parviflora* and *Lycium*

ferocissimum (Appendices 1 & 2).

The results of the strip transect sampling on Penguin Island are presented in Table 3. For each species recorded a percentage frequency was calculated for its occurrence on each transect (eg. a species which occurred on 3 of the 10 plots on a transect would have F% = 33.3). An overall percentage frequency was also calculated. The abundance of each species on each transect was expressed by the mean Domin Value. This is a simplified scale by which the percentage cover of a species within a transect can be estimated. The higher the Domin Value, the greater the percentage cover (Slingsby and Cook, 1986).

The important weeds on the northern plateau of Penguin Island were herbaceous *Malva parviflora*, *Rhaphanus raphanistrum* and *Sonchus oleraceus*, and the grass *Lolium rigidum*. The dominant weeds on the southern plateau were similar but *Sisymbrium orientale* replaced *Rhaphanus* and

Table 3. Plant frequencies (from transect data)

SPECIES RECORDED	P1a (55m)		P1b (50m)		P1c (50m)		P2a (60m)	
	F%	Domin Value	F%	Domin Value	F%	Domin Value	F%	Domin Value
<i>Acacia rostellifera</i>								
<i>Acanthocarpus preissii</i>								
<i>Alyxia buxifolia</i>								
<i>Carpobrotus virescens</i>	9		40	5.9	10			
<i>Cassytha racemosa</i>								
<i>Clematis linearifolia</i>								
<i>Enchylaena tomentosa</i>			10				58.3	3
<i>Frankenia pauciflora</i>			20	5.9			8.3	3.9
<i>Lepidium foliosum</i>							50	3
<i>Lepidosperma gladiatum</i>								
<i>Nitraria billardierei</i>							8.3	3.9
<i>Ozothamnus cordatus</i>								
<i>Rhagodia baccata</i>	54.5	3.9	70	7.4	100	7.4	100	4.6
<i>Scaevola crassifolia</i>								
<i>Senecio lautus</i>								
<i>Spinifex longifolius</i>			20					
<i>Spyridium globulosum</i>								
<i>Austrostipa elegantissima</i>								
<i>Austrostipa flavescens</i>								
<i>Tetragonia implexicoma</i>								
<i>Threlkeldia diffusa</i>	9				30	3	16.6	3
* <i>Avena fatua</i>			20		20			
<i>Bromus arenarius</i>			30	3	20		33.3	3.9
* <i>Ehrharta longiflora</i>								
* <i>Euphorbia peplus</i>								
* <i>Euphorbia terracina</i>								
* <i>Hordeum leporinum</i>					10			
* <i>Lavatera arborea</i>	9							
* <i>Lavatera cretica</i>					10	4.6		
<i>Lolium rigidum</i>			40		10	3	66.6	3.9
* <i>Malva parviflora</i>	81.8	5.9	10	3.9	40	5.9	83.3	3.9
* <i>Melilotus indica</i>			10		10		16.6	
* <i>Raphanus raphanistrum</i>	63.6	7.4						
* <i>Sisymbrium orientale</i>	9		20		60		75	4.6
* <i>Solanum nigrum</i>	9						8.3	
* <i>Sonchus oleraceus</i>			50		70	2.6	58.3	3.9
* <i>Tetragonia decumbens</i>	45.4	3			10	5.9	8.3	5.9
* <i>Trachyandra divaricata</i>			10		10		33.3	2.6
BARE SOIL	18	3.9			20	5.9	25	3

P2b (45m)		P3a (200m)		P4a (105m)		P5a (105m)		P6a (80m)		OVERALL
F%	Domin Value	F%	Domin Value	F%	Domin Value	F%	Domin Value	F%	Domin Value	F%
		45	5.9	14.3	2.6					14
		35	2.6							9
		15	3							4
III.1	3.9	7.5	3	23.8	4.6	33.3	4.6	12.5	3	17
		5	2.6							1
		27.5	2.6							7
III.1				9.5				25	3	15
						4.8	2.6	18.7	2.6	6
										5
		10	3							3
III.1								6.2	3	2
		2.5	2.6							1
100	5.9	80	3.9	42.8	3.9	71.4	4.6	81.2	5.9	75
		17.5	3.9	28.5	3.9					9
		7.5		9.5						3
		32.5	3.9	4.7	3	14.3	3			13
		2.5	3							1
		17.5	2.6							5
		12.5	5.9							3
		25	3							7
		2.5				4.8	2.6			6
										3
44.4	3.9	22.5	3	52.3	4.6	9.5	2.6	18.7	3	25
		2.5								1
				14.3	3.9					2
								25	3	3
										1
								12.5	2.6	2
										1
22.2	3.9	10	2.6	19	4.6	9.5	2.6	12.5	3	18
33.3	3							81.2	5.9	27
22.2	3.9	2.5	2.6							5
										5
100	4.6	10	3.9	28.6		9.5	3	43.7	3.9	31
		5								3
66.6	3.9	27.5	2.6	19		33.3	2.6	37.5	3	35
		67.5	5.9	100	5.9	95.2	4.6			63
III.1	2.6	40	3	80.9	3.9	47.6	4.6			33
33.3	3.9	33.3	3.9	57.1	3.9	28.5	3	12.5	3.9	29

Trachyandra divaricata became important.

Introduced weeds are generally not dominant in the sandy parts of the island, especially if one excludes long naturalised dune colonisers such as *Tetragonia decumbens*; however *Trachyandra divaricata*, *Sonchus oleraceus* and *Malva parviflora* recurred at a high frequency. Two of the most important weeds in terms of ground cover *Malva parviflora* and *Rhaphanus raphanistrum* have been introduced since 1961 and 1984 respectively and may be in an invasive stage.

The introduced hollyhock *Lavatera cretica* has recently colonised Penguin Island and is currently restricted to one discrete patch on the northern plateau. African Boxthorn (*Lycium ferocissimum*) has been recorded in the southern part of Penguin Island for the first time.

The most significant weed on the smaller islands is the tree mallow (*Lavatera arborea*), a tall, robust and relatively long-lived coprophilous species. It forms dense forest-like stands, up to 3m high, on Bird Island and has taken over the core of Seal Island during the past two years. The proliferation of this species on Seal Island followed the expansion of Pied Cormorant colonies onto and across this island in 1995 (J.N. Dunlop pers. obs.). The stand on Seal Island in 1997 was effectively excluding other plant species, including the native Hollyhock *Lavatera plebeia*. Birds such as Little Penguins, Silver Gulls and Bridled Terns which had formerly nested over

the invaded area were also excluded.

Finally further mention must be made of the African Boxthorn (*Lycium ferocissimum*) on Penguin Island. This may well have been present at the time of the survey, but was not noted until some six months later in March 1998, when one large clump of bushes of about 10sq m in area by 2m in height and four smaller neighbouring bushes were present and were in flower. This is the first record of Boxthorn on the Shoalwater Bay islands.

DISCUSSION

Vegetation cover appears variable. It is possible that the reduced cover in 1953 followed on the use of Penguin Island for military purposes during the World War II and thereafter. There are also reports of guano collection on the southern plateau. Gradual recovery may have taken place until the formation of Penguin Island Pty Ltd in 1969 when holiday accommodation was built (FSIMP 1995).

By 1980 visitor pressure may have accounted for devegetation which was quite pronounced. A myriad of tracks criss-crossed the island between the eastern and western beaches. Following the acquisition of the lease in 1987 by the government, and the introduction of dune management with construction of boardwalks, continued improvement took place and vegetation cover in 1997 appeared satisfactory.

Storr (1961) used the flora of the

Table 4. Birds which nest on the Shoalwater islands

Island	Nest on shrubs			Nest on ground surface					Make burrows		
	Pied Cormorant	Little Pied Cormorant	Crested Terns	Bridled Terns	Caspian Terns	Roseate Terns	Silver Gulls	Feral Pigeons	Little Penguin	Little Shearwater	Whitefaced Storm Petrel
Penguin		+		++			++	+	++	+	
Seal	++		+	++			++	+			
Bird	+			++	+		++	+	+		
Middle Shag	++			++			++	+			+
West Shag	+			+			+	+			
East Shag				+			+	+			
Gull Rock				+			+	+			

+ = 1-10 pairs + = 11-100 pairs ++ = 101-1,000 pairs

islands of Shoalwater Bay to demonstrate a log - linear relationship between land area and plant species richness. Slight deviations in this relationship resulted when islands had an east-west rather than north-south orientation leading to more exposure and reduced sand accumulation. In practice the relationship was between the number of plants and the number of available habitats which in turn were related to area and orientation. The Shoalwater Bay Islands also show the other trends of island biogeography such as a turnover of species the rate of which is determined, amongst other things, by the distance from the mainland (Abbott 1977).

Small islands with no predatory mammals are frequently used as secure nesting grounds by seabirds. The numbers of birds at these colonies are determined by food availability in the marine environment and densities vastly exceed those experienced on larger islands or coastal areas. The mechanical damage and heavy manuring from nesting and roosting seabirds is a source of almost constant disturbance. Gillham (1961) described the ecological changes induced by seabird and sealion activity on the vegetation of aeolianite and granitic islands off south-western Australia. Burrowing and surface nesting seabirds were also observed to have slightly different effects on island vegetation. Table 4 lists the islands and the current bird nesting populations.

Heavy disturbance pressures from surface-nesting seabirds may

result in a form of secondary plant succession, in which the general tendency is for sclerophylls to become replaced by succulents, shrubs by trailing herbs, perennials by annuals and indigenous plants by aliens (Gillham 1961).

The most extreme impact on island vegetation occurs in the nesting areas of large body weight species which form dense colonies, such as Pied Cormorants and Crested Terns. Currently Pied Cormorants are nesting on Seal Island and Middle Shag Island in considerable numbers and it is these islands which show the greatest depletion of native species in the survey. These seabirds frequently shift or alternate nesting areas (Wooller & Dunlop 1981, Dunlop 1987) so that the impact on colony vegetation is episodic. During a breeding episode woody vegetation and succulent shrubs are killed by a combination of mechanical damage and foliar scorching and toxic soil nitrogen levels due to accumulation of guano. In subsequent seasons the site is colonised by coprophilous shrubs, including Hollyhocks *Lavatera* spp. Should the site remain abandoned, and soil conditions ameliorate, the Hollyhocks may be replaced by re-establishing woody shrubs. However should nesting pressure continue the vegetation may be reduced to annual herbs, most of which are introduced weed species (Gillham 1961).

Another group of surface-nesting seabirds, including Silver Gulls and Bridled Terns, nest in large colonies but at lower densities.

Breeding pairs retain nest sites over successive seasons and colony areas are occupied permanently (Wooller & Dunlop 1979, Dunlop & Jenkins 1992 & 1994). The vegetation in these colonies tends to be maintained in equilibrium, with the spaces between clumps of woody or succulent shrubs maintained by the near nest activity of the territorial birds. Depending on the disturbance pressures these spaces may be vegetated (at least in winter and spring) by Hollyhocks and/or annual herbs and grasses.

The vegetation of seabird islands is subject to high levels of "natural" disturbance. This factor, together with elevated levels of soil nitrogen and phosphorus enhances colonisation by weed species, particularly introduced herbs and grasses and plants which thrive in the presence of high concentrations of guano or manure (e.g. Hollyhocks). The proximity of the aeolianite islands to the mainland has meant that these islands have been exposed to an ever-increasing number of weed species since European settlement.

In 1997 half of the flora of the Shoalwater Islands consisted of introduced herbs, grasses and short-lived coprophilous shrubs or Hollyhocks. Many of the dominant weeds such as *Malva parviflora*, *Rhaphanus raphanistrum*, *Sisymbrium orientale*, *Trachyandra divaricata*, *Sonchus oleraceus* and *Lolium rigidum* are low herbs or grasses which have little impact on habitat quality. There is also little evidence that these mainly annual species have any

significant impact on the regeneration of the low woody bushes and succulent shrubs which are important features of seabird nesting habitats.

The introduced coprophilous shrub *Lavatera arborea* however is a tall woody perennial which, under certain circumstances, forms closed stands capable of excluding regenerating shrub species and making the affected habitat area unsuitable for nesting Little Penguins, Silver Gulls, Bridled Terns and other surface nesting species. Boxthorn (*Lycium ferocissimum*), which has only just been noted, could also interfere with nesting habitats if allowed to become established.

The smaller islands have seen a dramatic reduction in plant species richness and habitat quality in recent years. The catalyst for this has almost certainly been an increase in the number of breeding seabirds. This has been documented for the Silver Gull (Dunlop *et al.* 1988) and the Bridled Tern (Dunlop & Jenkins 1994).

The numbers of Pied Cormorants have not been monitored but it is clear that in recent years these guano-producing birds have nested on more islands and over a larger area than in 1942 (Serventy & White 1943). Observations in April 1996 also indicated that the number of cormorants nesting on Carnac Island had increased dramatically since 1984 as had the area of vegetation affected by cormorant colonies (Dunlop & Wooller 1981, J.N. Dunlop pers. obs.). On Carnac these changes had obliterated former breeding

habitat of Little Penguins and Wedge-tailed Shearwaters. It is reasonable to assume that the number of cormorants nesting in Shoalwater Bay has also increased.

The relationship between expanding cormorant colonies, the loss of woody and succulent shrub species and the dominance of coprophilous *Lavatera arborea* underlies the observed decline in habitat quality on the smaller islands, particularly on Bird and Seal Islands. The recent colonisation of another introduced woody Hollyhock *Lavatera cretica* may also be of significance for future vegetation/habitat management.

CONCLUSION

Vegetation cover on Penguin Island has changed over the years, presumably in response to various pressures, mostly human, which are exerted upon it. At present this island appears reasonably well vegetated.

The number or variety of species represented in the vegetation appears to have remained fairly constant for Penguin Island, but the smaller islands, less subject to people pressure, show a marked depletion in species number varying from 43% to 100%. The small islands are not subject to human influences but are the sites of large and increasing populations of nesting birds, which account for destruction of native vegetation and the introduction of exotic species or weeds. There has been significant depopulation of indigenous species on the smaller islands.

Large areas of the smaller islands on which Pied Cormorants nest, Seal and Bird, have been taken over by mixed communities of Malvaceae, particularly *Lavatera arborea* and *Malva parviflora*, which are displacing or have displaced the indigenous vegetation including the native *Lavatera plebeia*. These intruders may exclude other vegetation regrowth as well as interfering with future bird nesting patterns.

On Penguin Island some communities of weeds belonging to the Brassicaceae are becoming prominent over relatively small areas and African Boxthorn (*Lycium ferocissimum*) has been observed for the first time.

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APPENDIX 1

LISTS OF PLANTS FROM PENGUIN ISLAND:

1959¹ reported by Storr (1961)

1975² reported by Abbott and Black (1980)

1984³ reported by Chape (1984)

1997/98 current study

	1959 ¹	1975 ²	1984 ³	1997/98
Juncaginaceae				
<i>Triglochin trichophora</i> Nees		+		
Poaceae				
* <i>Avena barbata</i> Link.		+		
* <i>Avena fatua</i> L.	+		+	+
<i>Bromus arenarius</i> Labill.	+		+	
* <i>Bromus diandrus</i> Roth	+	+	+	+
* <i>Cynodon dactylon</i> (L.) Pers.		+		
* <i>Ehrharta longiflora</i> Sm.	+	+	+	+
* <i>Hordeum leporinum</i> . Link		+		+
* <i>Lagurus ovatus</i> L.		+		
* <i>Lolium perenne</i> L.				+
* <i>Lolium rigidum</i> Gaudin	+	+	+	+
* <i>Parapholis incurva</i> (L.)C.E. Hubb.	+		+	+
* <i>Poa annua</i> L.	+	+	+	+
<i>Poa poiformis</i> (Labill.) Druce	+	+	+	
<i>Spinifex hirsutus</i> Labill.	+	+	+	+
<i>Spinifex longifolius</i> R.Br.	+	+	+	+
<i>Sporobolus virginicus</i> (L.)Kunth	+	+		+
* <i>Stenotaphrum secundatum</i> (Walter)Kuntze	+	+	+	+
<i>Austrostipa elegantissima</i> Labill.		+		+
<i>Austrostipa flavescens</i> Hughes (<i>S. variabilis</i>)	+	+	+	+
* <i>Trachynia distachya</i> (L.)Link (<i>Brachypodium distachyon</i>)	+		+	
* <i>Vulpia myuros</i> (L.)C.C.Gmel.	+		+	
Cyperaceae				
<i>Isolepis marginata</i> (Thunb.)Dietr. (<i>Scirpus antarctica</i>)	+	+	+	
<i>Isolepis nodosa</i> (Rottb.)R.Br. (<i>Scirpus nodosus</i>)	+	+	+	
<i>Lepidosperma gladiatum</i> Labill.	+	+	+	+
Dasypogonaceae				
<i>Acanthocarpus preissii</i> Lehm.	+	+	+	+
Asphodelaceae				
* <i>Trachyandra divaricata</i> (Jacq.)Kunth.	+	+	+	+
Iridaceae				
* <i>Romulea rosea</i> (L.) Eckl.		+		+
Haemodoraceae				
<i>Conostylis candicans</i> Endl.	+	+	+	+

	1959 ¹	1975 ²	1984 ³	1997/98
Urticaceae				
<i>Parietaria debilis</i> G. Forst.	+	+	+	+
* <i>Urtica urens</i> L.			+	+
Polygonaceae				
<i>Muehlenbeckia adpressa</i> (Labill.)Meisn.	+	+	+	+
Chenopodiaceae				
* <i>Atriplex prostrata</i> M Boucher ex DC.				+
* <i>Chenopodium ambrosioides</i> L.				+
<i>Enchylaena tomentosa</i> R.Br.	+	+	+	+
<i>Rhagodia baccata</i> (Labil.)Moq.in A.DC.	+	+	+	+
<i>Sarcocornia blackiana</i> (Ulbr)A.J.Scott		+		
<i>Sarcocornia quinqueflora</i> Bunge ex Ung.-Sternb.)A.J.Scott	+		+	+
<i>Salsola kali</i> L.	+		+	
<i>Threlkeldia diffusa</i> R.Br.	+	+		+
Aizoaceae				
* <i>Carpobrotus edulis</i> (L.)N.E.Br.in E.Phillips	+		+	
<i>Carpobrotus virescens</i> (Haw)Schwantes	+	+	+	+
* <i>Galenia pubescens</i> (Ecklon& Zeyher) Druce				+
* <i>Tetragonia decumbens</i> Mill.	+	+	+	+
<i>Tetragonia implexicoma</i> (Miq.)Hook.f.	+	+	+	+
Portulacaceae				
<i>Calandrinia calypttrata</i> Hook f.	+	+	+	
Caryophyllaceae				
* <i>Cerastium glomeratum</i> Thuill.(C. viscosum)	+	+	+	
* <i>Polycarpon tetraphyllum</i> (L.)L.	+		+	+
* <i>Sagina maritima</i> Don.				+
* <i>Spergularia rubra</i> (L.)J.Presl & C.Presl	+	+	+	
* <i>Stellaria media</i> (L.)Vill.	+	+	+	
Ranunculaceae				
<i>Clematis linearifolia</i> Steud.in Lehm. (C. microphylla)	+	+	+	+
Fumariaceae				
* <i>Fumaria capreolata</i> L.				+
* <i>Fumaria muralis</i> Sonder ex Koch.		+		
Lauraceae				
<i>Cassytha racemosa</i> Nees	+	+	+	+
Brassicaceae				
* <i>Brassica rapa</i> L.				+

	1959 ¹	1975 ²	1984 ³	1997/98
* <i>Cakile maritima</i> Scop.	+	+	+	+
* <i>Hymenolobus procumbens</i> (L.) Nutt ex Shinz & Thell.		+		
<i>Lepidium foliosum</i> Desv.		+		+
* <i>Sisymbrium orientale</i> L.	+	+	+	+
* <i>Raphanus raphanistrum</i> L.				+
Crassulaceae				
<i>Crassula colorata</i> (Nees) Ostenf.	+	+	+	
* <i>Crassula glomerata</i> P.Bergius	+	+	+	
<i>Crassula pedicellosa</i> (F. Muell.) Ostenf. (<i>Crassula closiana</i>)		+		+
Pittosporaceae				
<i>Pittosporum phylliraeoides</i> DC.	+	+	+	+
Mimosaceae				
<i>Acacia cyclops</i> A.Cunn. ex G.Don	+		+	+
<i>Acacia rostellifera</i> Benth.	+	+	+	+
Papilionaceae				
<i>Hardenbergia comptoniana</i> (Andrews) Benth. in Endl.		+		+
* <i>Medicago polymorpha</i> L.	+	+	+	
* <i>Melilotus indica</i> (L.) All.	+	+	+	+
Geraniaceae				
* <i>Erodium moschatum</i> (L.) L'Her.				+
* <i>Geranium molle</i> L.		+		
* <i>Pelargonium capitatum</i> (L.) L'Her.		+		+
Oxalidaceae				
* <i>Oxalis corniculata</i> L.	+	+	+	
* <i>Oxalis pes-caprae</i> L.				+
Zygophyllaceae				
<i>Nitraria billardiieri</i> DC. (<i>N.schoberi</i>)	+	+	+	+
Santalaceae				
<i>Exocarpos sparteus</i> R.Br.		+		+
Euphorbiaceae				
* <i>Euphorbia peplus</i> L.		+		+
* <i>Euphorbia terracina</i>		+		+
Rhamnaceae				
<i>Spyridium globulosum</i> (Labill.) Benth.	+	+	+	+
Malvaceae				
* <i>Lavatera arborea</i> L.		+	+	+
<i>Lavatera plebeia</i> Sims			+	
* <i>Lavatera cretica</i> L.				+
* <i>Malva parviflora</i> L.		+		+
Frankeniaceae				
<i>Frankenia pauciflora</i> DC.	+	+	+	+

	1959 ¹	1975 ²	1984 ³	1997/98
Apiacea (Umbelliferae)				
<i>Apium prostratum</i> Labill. ex Vent. (<i>A. australe</i>)	+	+		+
Primulaceae				
* <i>Anagallis arvensis</i> L. (<i>A. foemina</i>)	+	+	+	+
Apocynaceae				
<i>Alyxia buxifolia</i> R.Br.	+	+	+	+
Convolvulaceae				
<i>Dichondra repens</i> J.R. Forster & G.Forst.	+	+	+	
<i>Wilsonia backhousei</i> Hook.f.	+	+	+	+
Solanaceae				
<i>Anthocercis littorea</i> Labill.	+			
* <i>Lycium ferocissimum</i> Miers				+
				30/03/98
* <i>Solanum nigrum</i> L.	+	+	+	+
Scrophulariaceae				
* <i>Bellardia trixago</i> (L.) All.		+		
* <i>Dischisma arenarium</i> E.Mey.	+	+	+	
Myoporaceae				
<i>Eremophila glabra</i> (R.Br.)Ostenf.		+		+
<i>Myoporum insulare</i> R.Br.(<i>M. adscendens</i>)	+	+	+	+
Rubiaceae				
* <i>Galium murale</i> (L.) All.		+		
Goodeniaceae				
<i>Scaevola crassifolia</i> Labill.	+	+	+	+
Asteraceae				
<i>Angianthus cunninghamii</i> (DC.)Benth.	+		+	
* <i>Arctotheca calendula</i> (L.)Levyns	+	+	+	+
* <i>Arctotheca populifolia</i> (P.J.Bergius)Norl. (<i>A. nivea</i>)			+	
<i>Leucophyta brownii</i> Cass. (<i>Calocephalus brownii</i>)		+		+
* <i>Carduus tenuiflorus</i> Curtis	+		+	
* <i>Conyza canadensis</i> (L.)Cronquist (<i>Erigeron canadensis</i>)	+		+	
* <i>Hypochaeris glabra</i> L. (<i>H. radicata</i> M)	+		+	
* <i>Lactuca saligna</i> L.		+		
<i>Olearia axillaris</i> (DC.)F.Muell.ex Benth.	+	+	+	+
<i>Ozothamnus cordatus</i> (DC.)Anderb. (<i>Helichrysum cordatum</i>)	+	+	+	+
<i>Senecio lautus</i> G.Forst.ex Willd.	+	+	+	+
* <i>Senecio tamoides</i> DC.				+
* <i>Sonchus oleraceus</i> L.	+	+	+	+

APPENDIX 2

LISTS OF PLANTS FROM THE SMALLER SHOALWATER BAY ISLANDS

1959¹ as reported by Storr (1961)
 1975² as reported by Abbott and Black (1980)
 1997³ current study

SEAL ISLAND (Area 1.2 ha)	1959 ¹	1975 ²	1997 ³
Poaceae			
<i>Bromus arenarius</i> Labill.	+		
* <i>Bromus diandrus</i> Roth (<i>B. gussoni</i> , <i>B. maximus</i>)	+	+	
* <i>Hordeum leporinum</i> Link	+	+	
* <i>Lolium rigidum</i> Gaudin	+		+
* <i>Poa annua</i> L.	+	+	
<i>Spinifex longifolius</i> R.Br.	+		
<i>Sporobolus virginicus</i> (L.) Kunth	+	+	
Dasygongonaceae			
<i>Acanthocarpus preissii</i>	+		
Asphodelaceae			
* <i>Trachyandra divaricata</i> (Jacq.) Kunth.	+		
Urticaceae			
<i>Parietaria debilis</i> G. Forst	+	+	
Chenopodiaceae			
<i>Atriplex cinerea</i> Poir.	+		
* <i>Atriplex prostrata</i> M.Boucher ex DC (<i>A. patula</i>)		+	+
* <i>Chenopodium murale</i> L.		+	+
<i>Enchylaena tomentosa</i> R.Br	+	+	+
<i>Rhagodia baccata</i> (Labill.) Moq.in A.DC	+	+	+
<i>Salsola kali</i> L.	+		
<i>Threlkeldia diffusa</i> R.Br.	+	+	
Aizoaceae			
<i>Carpobrotus virescens</i> (Haw.) Schwantes	+	+	+
* <i>Tetragonia decumbens</i> Mill.	+	+	+
<i>Tetragonia implexicoma</i> (Miq.) Hook. f	+	+	
Portulacaceae			
<i>Calandrinia calyptrata</i> Hook f.	+	+	
Caryophyllaceae			
* <i>Spergularia rubra</i> (L.) J&C Presl.		+	
* <i>Stellaria media</i> (L.) Vill.		+	
Brassicaceae			
* <i>Cakile maritima</i> Scop.	+		
* <i>Hymenolobus procumbens</i> (L.)	+	+	
<i>Lepidium foliosum</i> Desc.	+	+	+
* <i>Sisymbrium orientale</i> L.	+	+	+
Crassulaceae			
<i>Crassula colorata</i> (Nees)	+	+	
<i>Crassula pedicellosa</i> (F. Muell.) Ostenf.		+	

Pittosporaceae				
<i>Pittosporum phylliraeoides</i> DC.	+			
Papilionaceae				
* <i>Medicago polymorpha</i> L.	+			
* <i>Melilotus indica</i> (L.) All.	+	+		+
Geraniaceae				
* <i>Erodium cicutarium</i> (L.) L'Her. in Aiton	+	+		
Zygophyllaceae				
<i>Nitraria billardieri</i> DC (<i>N. schoberi</i>)	+	+		+
<i>Zygophyllum billardieri</i> DC	+			
Malvaceae				
* <i>Lavatera arborea</i> L.		+		+
<i>Lavatera plebeia</i> Sims	+	+		+
* <i>Malva parviflora</i> L.	+	+		+
Frankeniaceae				
<i>Frankenia pauciflora</i> DC.	+	+		
Umbelliferae				
<i>Apium prostratum</i> Labill. ex Vent. (<i>australe</i>)	+	+		+
Solanaceae				
* <i>Solanum nigrum</i> L.	+			
Myoporaceae				
<i>Myoporum insulare</i> R.Br. (<i>M. adscendens</i>)	+	+		+
Asteraceae				
* <i>Arctotheca calendula</i> (L.) Levyns	+			
* <i>Arctotheca populifolia</i> (P.J.Bergius)				
Norl. (<i>A. nivea</i>)	+			
<i>Olearia axillaris</i> (DC)F.Muell. ex Benth.	+			
<i>Senecio lautus</i> G.Forst. ex Willd.	+	+		
* <i>Sonchus oleraceus</i> L.	+	+		+
BIRD ISLAND Area 0.9ha				
	1959 ¹	1975 ²		1997 ³
Poaceae				
<i>Bromus arenarius</i> Labill.	+	+		
* <i>Hordeum leporinum</i> Link	+	+		+
* <i>Lolium rigidum</i> Gaudin	+	+		+
* <i>Poa annua</i> L.	+	+		
Asphodelaceae				
* <i>Trachyandra divaricata</i> (Jacq.) Kunth.				+
Urticaceae				
<i>Parietaria debilis</i> G. Forst.	+	+		+
Chenopodiaceae				
* <i>Atriplex prostrata</i> M. Boucher ex DC				+
* <i>Chenopodium murale</i> L.	+	+		+
<i>Enchylaena tomentosa</i> R.Br.	+	+		
<i>Rhagodia baccata</i> (Labill.) Moq. in A.DC	+	+		
<i>Threlkeldia diffusa</i> R.Br.	+	+		

Aizoaceae			
<i>Carpobrotus virescens</i> (Haw.) Schwantes	+	+	
* <i>Tetragonia decumbens</i> Mill.	+	+	+
Portulacaceae			
<i>Calandrinia calyptrata</i> Hook. f	+	+	
Caryophyllaceae			
* <i>Sagina apetala</i> Ard.		+	
* <i>Stellaria media</i> (L.) Vill.		+	
Brassicaceae			
<i>Lepidium foliosum</i> Desv.	+	+	
* <i>Sisymbrium orientale</i> L.	+	+	+
Crassulaceae			
<i>Crassula colorata</i> (Nees) Ostenf.	+	+	
<i>Crassula pedicellosa</i> (F.Muell.) Ostenf.		+	
Papilionaceae			
<i>Acacia rostellifera</i> Benth.	+		
* <i>Medicago polymorpha</i> L.	+		
* <i>Melilotus indica</i> (L.) All.	+	+	+
Geraniaceae			
* <i>Erodium cicutarium</i> (L.) L'Her.	+	+	
Oxalidaceae			
* <i>Oxalis corniculata</i> L.		+	
Zygophyllaceae.			
<i>Nitraria billardierei</i> DC	+	+	+
<i>Zygophyllum billardierei</i> DC.	+	+	
Malvaceae			
* <i>Lavatera arborea</i> L.	+	+	+
* <i>Malva parviflora</i> L.	+	+	+
<i>Lavatera plebeia</i> L.	+	+	+
Apiaceae			
<i>Apium prostratum</i> Labill. ex Vent. (<i>A. australe</i>)	+	+	
Solanaceae			
* <i>Solanum nigrum</i> L.	+		
Myoporaceae			
<i>Myoporum insulare</i> R.Br. (<i>M. adscendens</i>)	+	+	
Asteraceae			
* <i>Arctotheca calendula</i> (L.) Levyns	+	+	
<i>Olearia axillaris</i> (DC.) F. Muell. ex Beth.	+		
<i>Senecio lautus</i> G Forster ex Willd	+	+	
* <i>Sonchus oleraceus</i> L.	+	+	+

Note: White-faced Storm Petrel burrows were seen on the eastern island. These were on the middle of the south side, in steeply sloping sand above the cliff area, in *Lavatera arborea* forest.

GULL ROCK (Area 0.04ha)

	1959 ¹	1975 ²	1997 ³
Chenopodiaceae			
* <i>Chenopodium murale</i> L.		+	
<i>Threlkeldia diffusa</i> R.Br.		+	
Aizoaceae			
<i>Carpobrotus virescens</i> (Haw.) Schwantes	+	+	
Zygophyllaceae			
<i>Nitraria billardiarei</i> DC.	+	+	+
Malvaceae			
<i>Lavatera plebeia</i> Sims (sp)		+	

SHAG ROCKS

MIDDLE SHAG ROCK Area 0.4ha

	1959 ¹	1975 ²	1997 ³
Poaceae			
<i>Bromus arenarius</i> Labill.	+		
* <i>Bromus diandrus</i> Roth. (<i>B gussoni</i> , <i>B maximus</i>)	+		
* <i>Hordeum leporinum</i> . Link	+		
* <i>Lolium rigidum</i> Gaudin			+
<i>Sporobolus virginicus</i> (L.) Kunth		+	
Asphodelaceae			
* <i>Trachyandra divaricata</i> (Jacq.) Kunth.		+	
Urticaceae			
<i>Parietaria debilis</i> G. Forst.	+		
Chenopodiaceae			
* <i>Atriplex prostrata</i> M.Boucher ex DC. (<i>A. patula</i>)		+	+
<i>Enchylaena tomentosa</i> R.Br	+		
* <i>Chenopodium album</i> L.		+	+
* <i>Chenopodium murale</i> L.	+	+	+
<i>Rhagodia baccata</i> (Labill.)	+	+	
<i>Threlkeldia diffusa</i> R.Br.	+	+	
Aizoaceae			
<i>Carpobrotus virescens</i> (Haw.) Schwantes	+	+	+
* <i>Tetragonia decumbens</i> Mill.	+		
<i>Tetragonia implexicoma</i> (Miq) Hook. f.	+		
Portulacaceae			
<i>Calandrinia calypttrata</i> Hook. f.	+	+	
Brassicaceae			
<i>Lepidium foliosum</i> Desv.	+	+	+
* <i>Sisymbrium orientale</i> L.	+	+	+
Papilionaceae			
* <i>Melilotus indica</i> (L.) All.	+	+	
Geraniaceae			
* <i>Erodium cicutarium</i> (L.) L'Her.	+	+	

Zygophyllaceae			
<i>Nitraria billardieri</i> DC.	+	+	+
Malvaceae			
* <i>Lavatera arborea</i> L.		+	+
<i>Lavatera plebeia</i> Sims	+	+	+
* <i>Malva parviflora</i> L.	+	+	+
Apiaceae			
<i>Apium prostratum</i> Labill. ex Vent. (<i>A. australe</i>)	+	+	+
Solanaceae			
* <i>Solanum nigrum</i> L.	+		
Myoporaceae			
<i>Myoporum insulare</i> R.Br. (<i>M. adscendens</i>)	+	+	+
Goodeniaceae			
<i>Scaevola crassifolia</i> Labill.			+
Asteraceae			
* <i>Arctotheca calendula</i> (L.) Levyns		+	
<i>Senecio lautus</i> G.Forst. ex Willd.	+	+	+
* <i>Sonchus oleraceus</i> L.	+	+	+

WEST SHAG ROCK Area 0.16ha

	1959 ¹	1975 ²	1997 ³
Chenopodiaceae			
* <i>Atriplex prostrata</i> M. Boucher ex DC.		+	
* <i>Chenopodium murale</i> L.		+	
<i>Threlkeldia diffusa</i> R.Br.	+	+	
Aizoaceae			
<i>Carpobrotus virescens</i> (Haw.) Schwantes	+	+	
Portulacaceae			
<i>Calandrinia calyptata</i> Hook. f.	+	+	
Brassicaceae			
<i>Lepidium foliosum</i> Desv.		+	
* <i>Sisymbrium orientale</i> L.		+	
Fabaceae			
* <i>Melilotus indica</i> (L.) All.		+	
Zygophyllaceae			
<i>Nitraria billardieri</i> DC.	+	+	
Malvaceae			
<i>Lavatera plebeia</i> Sims	+	+	
Asteraceae			
<i>Senecio lautus</i> G. Forst. ex Willd.	+	+	
* <i>Sonchus oleraceus</i> L.		+	

EAST SHAG ROCK Area .04ha

	1959 ¹	1975 ²	1997 ³
Chenopodiaceae			
* <i>Chenopodium murale</i> L.		+	
<i>Threlkeldia diffusa</i> R.Br.	+	+	

Aizoaceae			
<i>Carpobrotus virescens</i> (Haw.)Schwantes	+	+	
Brassicaceae			
<i>Lepidium foliosum</i> Desv		+	
Zygophyllaceae			
<i>Nitraria billardierei</i> DC.	+	+	+
Malvaceae			
<i>Lavatera plebeia</i> Sims	+	+	